RDT&E PROJECT JUSTIFICATION SHEET (R-2)					February 2003			
OPERATIONAL TEST AND EVALUATION, DEFENSE (0460) BUDGET ACTIVITY THREE			TEST AND EVALUATION SCIENCE AND TECHNOLOGY (T&E/S&T) PROGRAM ELEMENT (PE) 0603941D8Z					
$'s in Millions	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	FY 2008	FY 2009
PE 0603941D	7.905	8.571	12.804	19.413	29.058	43.572	65.301	97.669
Spectrum Efficient Technology	2.924	2.200	3.067	3.640	3.897	4.122	4.600	5.305
Multi-Spectral Sensors T&E	2.835	1.565	2.168	2.192	2.664	3.382	5.015	7.575
Hypersonic Testing Technologies	1.605	2.411	2.731	4.082	5.827	10.929	17.822	26.690
Embedded Instrumentation	0.541	1.203	2.894	3.750	4.969	7.553	12.000	19.202
Directed Energy	0.000	1.202	1.944	4.084	4.584	6.913	9.807	15.210
Information Systems Technology	0.000	0.000	0.000	0.555	1.716	3.381	5.014	7.472
Modeling and Simulation	0.000	0.000	0.000	0.555	2.252	3.064	5.014	7.634

Test Range/Facility Productivity Improvement	0.000	0.000	0.000	0.555	2.237	3.065	4.079	5.512
Software Test Technology	0.000	0.000	0.000	0.000	0.912	1.163	1.950	3.069

A. (U) MISSION DESCRIPTION AND BUDGET ITEM JUSTIFICATION

This program allows test technologies to keep pace with evolving weapons technology, and is critical to ensuring that we have the capability to fully and completely test the advanced systems that will be fielded in the future. The operational demands under which the DoD conducts Test and Evaluation (T&E) of increasingly sophisticated weapon systems have grown considerably. Weapon technology is quickly outdistancing our ability to adequately test systems as they develop. The T&E/S&T program:

- exploits new technologies and processes to meet important T&E requirements,
- expedites the transition of new technologies from the laboratory environment to the T&E community,
- leverages/exploits commercial equipment and networking innovations to support the T&E community.

Additionally, the program examines emerging test requirements derived from transformation initiatives to identify needed technology areas and develop a long-range roadmap for technology insertion. This program leverages and employs applicable 6.2 applied research from the highly developed technology base in the DoD Service Laboratories and Test Centers, industry, and academia to accelerate the development of new test capabilities.

This Research Category 6.3 PE, Advanced Technology Development, develops and demonstrates high payoff technologies for current and future DoD test capabilities.

Program Accomplishments and Plans:

FY 2002 Accomplishments:

The FY 2002 T&E/S&T program was divided between launching T&E/S&T focus area investigations and developing roadmaps for future year projects. The most critical focus areas were apparent, and investigations supporting those focus area projects were awarded in the following T&E/S&T focus areas (and further detailed in accompanying R-2As). The focus area investigations initiated were a result of evaluation of proposals solicited via a Program Research and Development Announcement process that includes issuing Broad Agency Announcements per focus area, and various investigations of each focus area were awarded to industry, academia, or government investigators, or consortiums of these sources. The focus area projects were:

Spectrum Efficient Technology:

- Initiated investigations into the technical challenges to augmenting the aeronautical telemetry (TM) band in the 3-30GHz range.

- Initiated seven research projects that address technologies in high data rates, spectrally efficient telemetry systems, highly efficient modulation schemes, channel modeling, steerable beam, directional antenna TM concepts and time coding for TM in the super high frequency bands. Technology investigations in this focus area directly support the increasing data rates that advanced weapon systems require, alleviation of radio frequency spectrum usage encroachment, and support to acquisition programs and the World Radio Conference in CY 2007.

Multi-Spectral Sensors Test and Evaluation:

- Initiated investigations and evaluations of test technologies required to test complex multi-spectral sensor arrays and to provide multi-spectral test environments (that simulate battlefield environments) that stimulate the advanced weapon systems currently under development.
- Initiated four research investigations that address specific challenges to the test community in remote sensing systems, detector algorithms, hyperspectral thermal system modeling, hyperspectral sensor evaluation, multispectral scene generation and stimulation system, and a hyperspectral snapshot infrared (IR) measurement system. These investigations will advance the state of the art in testing of advanced multiband, multifunction, multimode sensors being developed as part of the weapons transformation initiatives.

Hypersonic Testing Technologies:

- Investigated technologies needed for test and evaluation of hypersonic (MACH 4 to 15) ground and flight test capabilities. Launched five investigations with applications for supporting T&E associated with ramjets, scramjets, hypersonic combustors, hypersonic weapon lethality and survivability assessment, high temperature engine components, stability and control, guidance and control, innovative flight test technologies for hypersonic vehicles, integrated propulsion and airframe testing, computational T&E tools, hypersonic flow diagnostics, and hypersonics aerothermodynamics. These investigations will directly support transformational initiatives such as air-breathing hypersonics technologies to be applied against time-critical targets and access to space.

Embedded Instrumentation:

- Investigated and developed requirements for, and benefits of, embedded, non-intrusive test instrumentation employing microelectronic, microelectromechanical systems (MEMS), and nano-size technologies. Initial investigations focused on micro-miniaturization of instrumentation components such as inertial measurement units, multi axis stress/strain gauges, field-programmable gate arrays with embedded analog/digital converters, wireless sensors, flight termination systems, and power supplies. And, co-hosted a workshop with Defense Advanced Research Projects Agency (DARPA) to identify leveraging opportunities for FY 2003 investigations. Embedded test instrumentation will be crucial to testing systems such as low observable, multi-spectral stealth and hypersonic weapons.
- Initiated a project to leverage work at Jet Propulsion Laboratory (JPL) to apply fuel cell technology to provide long duration non-intrusive instrumentation power.

In addition to the launching of T&E/S&T focus area projects, held workshops to develop a test technology roadmap that documents the near and long-term test capability shortfalls across nine focus areas, each requiring a number of investigations. Initiated work on a Test Technology Area Plan (TTAP) to portray the roadmaps for each focus area, and to show the linkages with the Department's other planning documents, such as the Quadrennial Defense Review report, Joint Vision 2020, the Defense Science and Technology Plan, the Joint Warfighting

Science and Technology Plan, and the Defense Planning Guidance. The TTAP is envisioned to ensure that the projects funded by the T&E/S&T program are timely to meet future T&E needs to support acquisition program and fielding of weapon systems.

FY 2003 Plans:

The TTAP, with associated roadmaps will be completed and issued. Congressional plus-up to the T&E/S&T permits restructuring of the program for FY 2003 to begin investigations following the focus area project roadmaps to address a new focus area project, directed energy test, increase the investigations to support the embedded instrumentation focus area, as well as continue and, in some cases, complete most critical and promising technology developments from FY 2002. Some of the investigations under the "spectrum efficient technology" and "multi-spectral" focus areas will wrap up, and a Broad Agency Announcement will be issued to initiate others. Projects in the "hypersonic" focus area will continue, and a new project to address plasma effects of RF transmissions from hypersonic vehicles will be addressed. Ongoing science and technology work that is applicable to the "embedded instrumentation" focus area will be leveraged into new investigations. Completed investigations and learning will start their transition to the T&E community; e.g., miniaturized fuel cell technology for supporting vehicular instrumentation suites can be applied to acquisition of T&E capabilities to support the Future Combat System program by the end of this year.

Directed Energy:

- Initiate technology investigations to improve T&E capabilities for determining capabilities and limitations of High-Energy Laser (HEL) weapons; e.g., survivable on-board instrumentation, ground truth off-board instrumentation, and atmospheric characterization. Additional work will be necessary in the out years to address the full gamut of T&E technologies for high-energy laser weapons, as well as to address high-power microwave weapons.

FY 2004 Plans:

A review of the T&E/S&T program by the Department during the FY 2004-2009 program review highlighted the need for increased resources in this program and an increase in fiscal guidance was provided. Investigations into other aspects of the focus area projects, as well as continuation and field testing of existing projects, in the critical core focus areas of embedded instrumentation, spectrum efficient technology, hypersonics, multi-spectral test technologies, and directed energy will be executed to meet the increasing demand for advanced test capabilities – see respective R-2a for each focus area project. T&E/S&T investigations will be focused on the basis of the roadmaps contained in the TTAP, and as result of contract awards resulting from a Program Research and Development Announcement process that will include Broad Agency Announcements and contract proposal selection.

FY 2005 Plans:

Funding level increases in FY 2005 will permit continuing investigations in the T&E technology focus area projects continuing from FY 2004, as well as initiating investigations in the focus area projects in information systems technology, in modeling and simulation, and test range/facility productivity improvement.

Information Systems Technology (IST)

Investigations in this focus area will be launched to provide the T&E technologies basic to provide capabilities required to ensure that the systems provided to the warfighter deliver the information assurance and survivability our forces need to support the transformation

initiative to acquire, verify, protect, and assimilate the information necessary to neutralize and dominate any future adversary. Applications of these technologies will support T&E of network-centric operations, Military Operations on Urban Terrain, and other information technology-intensive programs relying on capabilities for capturing and evaluating multiple simultaneous collaborative user communications, capturing human physical and psychological performance, instrumentation that does not interfere with or change the performance of the information system(s) under evaluation including with humans-in-the-loop, and the validation of IST modeling and simulations

Modeling and Simulation

Investigations in this focus area will be launched to address technological challenges to improving distributed modeling and simulation among various test ranges and facilities and to permit use of their capabilities from other locations, to model human performance, to supplement T&E of systems-of-systems, to enable aggregation and disaggregation among levels and fidelities of simulations, and to enable advances in architectures and M&S tools.

Test Range/Facility Productivity Improvement

Investigations will be launched to determine how to leverage technological advances for weapon systems and information systems technologies that can provide the technologies needed to improve the productivity of T&E ranges and facilities to mitigate the increasing scheduling limitations that will be imposed by the need for faster T&E tempo. The thrust of this project will be to improve the capability of the DoD test and evaluation infrastructure to support T&E missions, and to provide the data and reports meet the schedules to meet the transformation goals requiring technology transitions to expedite processes, minimizing the expenditure of human capital, and to reducing costs.

B. **(U) PROGRAM CHANGE SUMMARY**

($ in Millions)	FY 2002 Appropriation	FY 2003 President's Budget	FY 2004 President's Budget	FY 2005 President's Budget
FY 2003 President's Budget	7.944	6.010	5.974	5.912
Current Budget Submit	7.905	8.571	12.804	19.413
Total Adjustments	(0.039)	2.561	6.830	13.501
Congressional Program Reductions		(0.173)		
Congressional Rescissions	(0.039)			
Congressional Increases		2.800		
Program Adjustment			7.226	13.888
Inflation Adjustment		(0.066)	(0.396)	(0.387)

C. (U) OTHER PROGRAM FUNDING NA

RDT&E PROJECT JUSTIFICATION SHEET (R-2a)				February 2003				
OPERATIONAL TEST AND EVALUATION, DEFENSE (0460) BUDGET ACTIVITY THREE, PE 0603941D				SPECTRUM EFFICIENT TECHNOLOGY				
$'s in Millions	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	FY 2008	FY 2009
Spectrum Efficient Technology	2.924	2.200	3.067	3.640	3.897	4.122	4.600	5.305
RDT&E Articles	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

A. (U) MISSION DESCRIPTION AND BUDGET ITEM JUSTIFICATION

One of the most immediate impacts to transitioning acquisition programs to the warfighters is the increasing radio frequency spectrum limitations, and the higher demands for bandwidth for more data. Full, realistic testing of modern military systems, and follow-on training at the completion of the system's development phase, rely heavily on the use of radio frequency (RF) spectrum, especially in the "L" and "S" microwave bands. Signal propagation, supportable data rates, and other related characteristics make these bands ideally suited for test telemetry and training applications. However, it is these same characteristics that make these bands highly coveted by the wireless communications industry. The growth in the demand for consumer communication services has resulted in pressure from the commercial telecommunications industry for the reallocation of RF spectrum from government to non-government use. Since 1992, DoD has lost approximately 27 percent of the total spectrum allocated for aircraft telemetry through congressionally mandated spectrum reallocations and other regulatory mechanisms to accommodate these consumer services. The reallocation of this spectrum, coupled with the increase in activities that use it, has raised concerns regarding the availability of adequate spectrum to support test and training. Current major flight test programs such as the F-22, and future programs such as the Joint Strike Fighter, Airborne Laser, and National Missile Defense, as well as weapons with multi-band/multi-mode seekers, advanced stealth, extended range/large footprints, supersonic and hypersonic systems, directed energy, and offensive and defensive space systems, will experience increased competition for spectrum among themselves and from other DoD programs. Also, spectrum limitations are impacting interoperability among the test and training ranges until a common set of frequencies can be found to permit extended range/large footprint vehicles to operate across multiple ranges. Development of new technologies is required to find ways to increase the efficiency of the remaining spectrum allocations, and to begin investigations into possible use of unused or lesser-used parts of the spectrum.

Each new generation of military systems such as satellite positioning, precision guided munitions, communications relay, and tactical combat training typically generates ten times more data and information than its predecessor, resulting in a 20-year trend of exceptional growth in the demand for test- and training-related spectrum. The Defense Science Board also recognized the need for adequate spectrum availability in its report titled, "Report of the Defense Science Board Task Force on DoD Frequency Spectrum Issues Coping with Change: Managing RF Spectrum to Meet DoD Needs," dated November 2000; as did "Report of the Defense Science Board Task Force on Test and Evaluation Capabilities," December 2000. The T&E/S&T program leverages S&T progress in wide-band communications, modulation, alternative frequency bands, antennas, and signal conditioning to provide technologies that can improve the efficiency of the spectrum and accommodate the increasing data rates.

B. (U) ACCOMPLISHMENTS/PLANNED PROGRAM

	FY 2002	FY 2003	FY 2004	FY 2005
Spectrum Efficient Technology	2.924	2.200	3.067	3.640
RDT&E Articles	N/A	N/A	N/A	N/A

FY 2002 Accomplishments:

In FY 2002, investigations were initiated in the technical challenges to augmenting the aeronautical telemetry (TM) band in the 3-30GHz range. Seven research investigations were initiated to begin addressing technologies in high data rate, spectrally efficient Telemetry systems, highly efficient modulation schemes, channel modeling, steerable-beam, directional antenna TM concepts and time coding for TM in the super high frequency bands. Technology investigations in this focus area directly support the increasing data rates and frequency spectrum usage that advanced weapon systems require.

Investigations underway are:

- Spectrally Efficient, High Data Rate Telemetry System in 3-30 Ghz: Design and simulate new approach to robust, high efficiency wireless links for aeronautical telemetry, and complementary integration of advanced modulation, new channel coding technique, and diversity techniques.
- Super High Frequency Channel Modeling: Modify Advanced Range Telemetry (ARTM) channel probe to operate in selected segments of Super High Frequency (SHF) range, and conduct field measurements under realistic test range conditions and update channel models.
- Variable Phase Shift Key (VPSK)/Feher Variant High Efficiency Modulations: Evaluate ultra-high spectrum efficiency modulation invented by H. Walker, and variants proposed by K. Feher.
- Space Time Coding for Aeronautical Telemetry: Exploit recent space-time coding theory advances to mitigate self-induced, co-channel interference tied to multiple transmit antenna configurations used in many flight test installations; design proposed coding method and use existing tools to simulate performance; and identify technology demonstration requirements, if warranted.
- Ground Based Receiving Telemetry Antennas: Researches advanced antenna technologies, variable beamwidth and parabolic antennas in SHF band.

- M-ary Variable Shift Keying: Complete theoretical design and simulate innovative high order, modulation free, frequency hopping spread spectrum technique; validate predictions with limited hardware emulation (breadboard level); and assess viability in-flight telemetry arena.
- Steerable Beam, Directional Antenna Concepts: Investigates transmitting antenna techniques above 3 Ghz through use of phase shifters to steer nulls, including open and closed-loop control systems.

FY 2003 Plans:

All investigations in this focus area from FY 2002 continue, some with new phases awarded, and all but the "Super High Frequency Channel Modeling" conclude. Among efforts this year will be to demonstrate an antenna in which beam steering will be accomplished by RF MEMS devices acting as radiating elements that could be applied to steerable gain antennas to increase telemetry link performance margins. Transitioning of resulting technologies from completed investigations will be initiated. Planning and prioritizing needs for investigation awards in 2004 will begin in accordance with the TTAP and the respective T&E/S&T roadmap, and utilize the Program Research & Development Announcement process for selection of investigators.

FY 2004 Plans:

Much work remains in this focus area not only to prepare the T&E community for supporting new weapon systems technology development and acquisition programs, but the 2007 World Radio Conference as well. Field testing for proof-of-concept of many of the developments from projects from previous years will be conducted in this year and in FY 2005. The "Super High Frequency Channel Modeling" investigation, started in FY 2002, will conclude. Additionally, investigations will be initiated as a result of the Program Research & Development Announcement process initiated in FY 2003, to address critical T&E technology issues in this focus area such as:

- Deconfliction of RF spectrum usage for T&E in joint urban operations, including Military Operations on Urban Terrain (MOUT).
- Smart (adaptive) antenna arrays for unobtrusive and non-interfering operations for system-under-test, and variable beamwidth directional antennas for frequency sharing.
- Techniques for overcoming transmission losses during ionization periods of hypersonic systems testing.
- More efficient and reliable portions of the RF spectrum for future telemetry, command control, and datalink communications for T&E and training.
- Advanced development of algorithms for data transmission bursts when ground reception stations are available.
- Ultra-high data rate pre-processing, compression, storage, and bandwidth- efficient modulation schemes for transmission.
- Remotely tunable datalink transceivers for security, safety, and inter-range operations.
- Doppler shift compensation for coherent receivers.

FY 2005 and Future Plans:

The T&E technology investigation issues identified for FY 2004 will continue to be worked.

C. (U) OTHER PROGRAM FUNDING NA

RDT&E PROJECT JUSTIFICATION SHEET (R-2a)				February 2003				
OPERATIONAL TEST AND EVALUATION, DEFENSE (0460) BUDGET ACTIVITY THREE, PE 0603941D				MULTI-SPECTRAL SENSORS TEST AND EVALUATION				
$'s in Millions	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	FY 2008	FY 2009
Multi-Spectral Sensors Test And Evaluation	2.835	1.565	2.168	2.192	2.664	3.382	5.015	7.575
RDT&E Articles	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

A. (U) MISSION DESCRIPTION AND BUDGET ITEM JUSTIFICATION

Numerous DoD science and technology programs are developing new technologies for use in multi-spectral sensors, seekers, detectors, and target designators for reconnaissance, surveillance, search, detection, location, identification, classification, weapons, and battle damage assessments. T&E of new multi-spectral technologies to be used in these future multi-spectral weapon systems will require new T&E technologies and operational integration. T&E investment programs, such as the Central Test and Evaluation Investment Program (CTEIP) and Service improvement and modernization programs, are addressing some basic multi-spectral requirements using off-the-shelf technologies; however, many of the needed capabilities for T&E of future multi-spectral technologies and systems will depend on technologies and procedures not yet developed or available for T&E purposes.

B. (U) ACCOMPLISHMENTS/PLANNED PROGRAM

	FY 2002	FY 2003	FY 2004	FY 2005
Multi-Spectral Sensors Test And Evaluation	2.835	1.565	2.168	2.192
RDT&E Articles	N/A	N/A	N/A	N/A

FY 2002 Accomplishments:

Initiated investigations and evaluations of test technologies required to test complex multi-spectral sensor arrays and to provide multi-spectral test environments (that simulate battlefield environments) that stimulate the advanced weapon systems currently under development. Four research investigations were initiated that address specific challenges to the test community in remote sensing systems; detector algorithms; hyperspectral thermal system modeling, hyperspectral sensor evaluation, multi-spectral scene generation and stimulation system and a hyperspectral snapshot IR measurement system. These investigations will advance the state of the art in testing of advanced multi-band, multifunction, multimode sensors being developed as part of the weapons transformation initiatives.

- Multispectral Signature Model: provide a "proof-of-principle tool for high-fidelity computer targets and backgrounds, an integrated T&E spectrum, and dynamic target background interaction.
- Ultraviolet – Short Wave Infrared (UV-SWIR) Hyperspectral Performance: develop a concept for testing and validating hyperspectral sensors via analysis of applications of various test types for hyperspectral sensor testing.
- Adaptive Multispectral Stimulator Injection Demonstration: provide a framework for a low-cost, scalable, portable and versatile multimode stimulator sensor injection system adaptable for T&E with a wide variety of sensors.
- Long Wave Infrared (LWIR) Hyperspectral Testbed Design: provide: (1) design for prototype hyperspectral testbed for use in a test laboratory environment; (2) integrated Acoustic-Optical Tunable Filter (AOTF), MEMS, and digital micro-mirror; and (3) develop performance data for parameters not covered by current data.

FY 2003 Plans:

In addition to the completion of all FY 2002 investigations except for the "Multispectral Signature Model" (which is scheduled for a FY 2004 completion), an investigation will be launched to determine the minimum resolvable temperature for a hyperspectral sensor evaluation tool.

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FY 2004 Plans:

Emphasis of the FY 2004 T&E/S&T program in this focus area will be to complete the investigation into the feasibility of a multi-spectral signature model, and to continue investigating the minimum resolvable temperature for a hyperspectral sensor evaluation tool initiated in FY 2003. Other investigations will be launched towards addressing the other test technology issues in this focus area project:

- Hyperspectral sensor data processing and analysis - real time
- Hyperspectral MWIR-LWIR data fusion test concept development
- Hyperspectral visible/near-IR scene generation model integration
- Common usage, tunable, full spectrum, and high-resolution scene generators
- Common usage, threat representative, full spectrum, and high-resolution dynamic target
- Common usage, threat representative, full spectrum, and high-resolution shallow underwater targets
- Capability to test focal plane array sensors, and frequency-hopping sensors
- Countermeasure environments and countermeasure applications

- Realistic all-weather scenario drivers and target presentations
- Environmental emulations for obscurants and anti-personnel agents, weather, and use of weapons of mass destruction and chemical biological warfare
- Angle of arrival stimulators
- Ladar, and other multispectral test generator and standoff sensors
- Develop an effective FPA sensor performance methodology
- MOUT scenarios
- Sensor-to-shooter system, and sensor-to-fusion-to-shooter system performance
- Far-field signal simulations in near-field
- Unobtrusive sensor integration and fusion monitoring
- Closed loop counter-countermeasure capabilities
- Hardware-in-the-loop and installed-system test facility capabilities
- Soldier-in-the-loop and associated MANPRINT issues
- Free space test instrumentation
- Focal plane array (FPA) technologies, frequency-hopping sensors, multispectral/hyperspectral imaging, active illumination, passive polarization, passive millimeter wave, foliage penetration, synthetic-aperture radar, and electronic stabilization
- Fusion of multiple advanced sensor components, the application of the aided target recognition algorithms to these advanced sensors
- Positive identification of non-cooperative air targets, over-the-horizon targeting, and battle damage assessment
- Tools to evaluate hyperspectral-polarimetric sensors
- Tools and techniques to evaluate active multispectral sensor systems
- Techniques for multi-spectral/hyperspectral focal plane array sensor performance testing
- T&E of signal processing hyperspectral algorithm effectiveness
- Sensor-to-shooter system interface analysis (human-in-the-loop testing)
- Hyperspectral analysis tool for handling and collating T&E data
- Methodologies for evaluating sensor-to-sensor transition (e.g. acoustic/IR, Millimeter Wave (MMW)/IR systems)

FY 2005 and Future Plans:

The T&E technology issues identified in FY 2004 will continue to be worked.

C. (U) OTHER PROGRAM FUNDING NA

RDT&E PROJECT JUSTIFICATION SHEET (R-2a)				February 2003				
OPERATIONAL TEST AND EVALUATION, DEFENSE (0460) BUDGET ACTIVITY THREE, PE 0603941D				HYPERSONIC TESTING TECHNOLOGIES				
$'s in Millions	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	FY 2008	FY 2009
Hypersonic Testing Technologies	1.605	2.411	2.731	4.082	5.827	10.929	17.822	26.690
RDT&E Articles	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

A. (U) MISSION DESCRIPTION AND BUDGET ITEM JUSTIFICATION

Hypersonic systems to be developed to attack time-critical and deep-hardened targets, and other transformational weapon systems to be built upon hypersonic technologies will challenge T&E capabilities in numerous areas ranging from ground testing (wind tunnels, sled tracks, installed-system test facilities, and modeling and simulation (including computational fluid dynamics), through flight testing (entailing large geographical areas and huge safety footprints). At hypersonic speeds, flight testing will also challenge existing ground instrumentation systems (e.g., tracking system slew rate limitations, ionization dropouts) and range safety decision making. Near-term hypersonic applications are focused on developing technologies for munitions and weapons for time critical and mobile targets, advanced global reach aircraft, and access to space platforms that will operate in the hypersonic speed regimes; i.e., Mach 4 to Mach 16. Hypersonic weapon systems will depend on several new technological thrusts such as in the areas of propulsion and engines, structures and materials, guidance and control, seekers and sensors, warheads and payloads, and weapons delivery techniques and end-game dynamics, each requiring supporting T&E capabilities to determine their performance, effectiveness, suitability, survivability, and responsiveness to Command, Control, Communications, computers, Intelligence, Surveillance and Reconnaissance (C4ISR) systems. T&E investment programs, such as the CTEIP and Service improvement and modernization programs, are addressing some basic test facility upgrades using off-the-shelf technologies; however, many of the needed capabilities for T&E of hypersonic systems are dependent on technologies not developed for T&E purposes.

B. (U) ACCOMPLISHMENTS/PLANNED PROGRAM

	FY 2002	FY 2003	FY 2004	FY 2005
Hypersonic Testing Technologies	1.605	2.411	2.731	4.082
RDT&E Articles	N/A	N/A	N/A	N/A

FY 2002 Accomplishments:

Began investigating technologies needed for test and evaluation of hypersonic (MACH 4+) ground test capabilities and flight testing to support research associated with ramjets, scramjets, hypersonic combustors, hypersonic weapon lethality and survivability assessment, high temperature engine components, stability and control, guidance and control, as well as innovative flight test technologies for hypersonic vehicles, integrated propulsion and airframe testing, computational T&E tools, hypersonic flow diagnostics, and hypersonic aerothermodynamics. These research investigations will directly support transformational initiatives such as time-critical target strike capabilities.

Investigations initiated in FY 2002 and continuing:

- Heat Flux Sensor for Hypersonic Aerothermal Measurements: Sensor technology development for use in flight and wind tunnel testing for measuring dynamic heat transfer under hypersonic conditions.
- Hypersonic Aeropropulsion System Flight Trajectory Test and Evaluation: Development of a long duration (minutes vice seconds) dynamic simulation of hypersonic vehicle performance testing for durability and operability.
- Hypersonic Wind Tunnel Nozzle Survivability for T&E: Improve high-temperature nozzle survivability using new refractory metal alloys and ceramic coating for application in hot hypersonic wind tunnels.
- In-Situ Pressure Measurements for Hypersonic Vehicles: Development of a MEM sensor, silicon carbide based, for pressure measurements in ramjet and scramjet combustors in flight and ground hypersonic vehicle testing.
- Advanced Flight Vehicle Instrumentation: Technology development for on-board data system with distributed array of light-weight high-temperature optical fibers for use in hypersonic flight testing and some ground testing.

FY 2003 Plans:

FY 2003 investigations will be primarily a continuation of FY 2002 investigations, in some cases starting a new phase. One additional investigation will be launched to examine plasma effects of hypersonic vehicles on T&E; i.e., determine methodology for minimizing data collection drop-outs during hypersonic flight testing due to ionization effects.

FY 2004 Plans:

Investigations will continue from those initiated in FY 2002 and FY 2003. Other investigations will be launched this and subsequent years to address the other T&E technology challenges in this focus area.

- Flight testing:
    - Providing continuous and survivable (at least through the test mission) telemetry, time-space position and attitude information, and command/control (including flight termination systems) through target engagement, all the while addressing safety and security. All of this while providing data for evaluation of performance, effectiveness, suitability, survivability, and recovery.

  - Providing inter-range operations, ground instrumentation (tracking, data stream reception), and range safety and non-destructive flight termination capabilities
- Ground testing:
  - Realistic ground test environments (wind tunnel, computational fluid dynamics (CFD), magnetohydrodynamics, installed-system test facility, sled track, high altitude propulsion test stands) and capabilities to adequately simulate flight conditions with associated targets and countermeasures conditions.
  - Onboard survivable sensors and instrumentation systems for both ground and flight testing: Test data transmission continuity and higher data rate encryption for:
- These challenges are to apply to T&E of hypersonic systems in the areas of:
  - Propulsion
  - Thermo management
  - Aerodynamic aerothermal heat and cooling
  - Guidance
  - Navigation
  - High velocity flight control
  - Seekers
  - Communications
  - Weapons separation and end-game dynamics
  - Structures and materials effects
  - Flight data display comprehensibility and reaction as well as instrumentation survivability

FY 2005 and Future Plans:

The T&E technology issues for this project will continue to be worked.

C. (U) OTHER PROGRAM FUNDING NA

RDT&E PROJECT JUSTIFICATION SHEET (R-2a)				February 2003				
OPERATIONAL TEST AND EVALUATION, DEFENSE (0460) BUDGET ACTIVITY THREE, PE 0603941D				EMBEDDED INSTRUMENTATION				
$'s in Millions	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	FY 2008	FY 2009
Embedded Instrumentation	0.541	1.203	2.894	3.750	4.969	7.553	12.000	19.202
RDT&E Articles	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

A. (U) MISSION DESCRIPTION AND BUDGET ITEM JUSTIFICATION

As recognized by Business Initiative Council (BIC) Initiative TE-08, embedded instrumentation for T&E, training, maintenance, and logistics sparing will significantly reduce the development, acquisition, and total ownership costs of new weapon and C4ISR systems. There is minimal space (if any) for adding instrumentation to new weapon systems subsequent to their development, and additional weight and power draw can adversely affect the weapon system performance. This is especially the case in small weapons such as miniature-unmanned vehicles and robotics, and targets used in T&E and training exercises. However, new technologies can be exploited to provide small non-intrusive embedded instrumentation that can be incorporated during platform design and development, and, in some cases, for incorporation into existing platforms. This embedded instrumentation can provide the required data for T&E, training, maintenance, and logistics support, and will add significant value to documenting system performance during combat missions. And the embedded instrumentation can support these capabilities throughout the life of a platform without modifications or add-ons. The T&E/S&T program can leverage emerging technologies, such as MEMS and micro-electronics and "nano-electronics," to create non-intrusive and fully capable embedded instrumentation.

Current generation of test instrumentation simply cannot meet future size and performance requirements. Weapon systems are integrating MEMS technology into their systems to achieve component and subsystem size reductions up to 400 times previous systems. As residents within these weapon systems, test instrumentation must also meet size and power budgets. Transition of MEMS technology into the test community is essential. RF MEMS technology offers 100 times reduction in power, 100 times reduction in size, and 10 times improvement in spectral efficiency. All of these are critical parameters for T&E instrumentation that will yield significant return on investment for future programs. Inertial MEMS, chip-scale atomic clock, and micro power generation initiatives offer similar transition opportunities and benefits in T&E.

(U) B. ACCOMPLISHMENTS/PLANNED PROGRAM

	FY 2002	FY 2003	FY 2004	FY 2005
Embedded Instrumentation	0.541	1.203	2.894	3.750
RDT&E Articles	N/A	N/A	N/A	N/A

FY 2002 Accomplishments:

Investigated and developed requirements for, and benefits of, embedded, non-intrusive test instrumentation employing MEMS and nano-size technologies. Initial investigations focused on micro-miniaturization of instrumentation components such as inertial measurement units, multiaxis stress/strain gauges, field-programmable gate arrays with embedded analog/digital converters, radio frequency switching, wireless sensors, and power supplies. Co-hosted a workshop with DARPA to identify leveraging opportunities for new start projects in FY 2003. Embedded test instrumentation will be crucial to testing systems such as low observable, multi-spectral stealth, and hypersonic weapons where size, weight, and power consumption of instrumentation can be intrusive on the system-under-test performance.

One investigation was initiated in FY 2002:

- Direct Methanol Fuel Cell System Ancillary Power Source For Armored Vehicle Instrumentation: design, fabricate and test a 300 Watt (W), 800 W hr/kg, direct methanol fuel cell power source based on state-of-art technology. This 300W system is to serve as non-intrusive long-life (100 hours) power source for armored vehicle instrumentation during testing.

FY 2003 Plans:

Technological issues for providing embedded instrumentation capabilities will be addressed over the next several years. Selection of the issues for investigations to begin in FY 2003 is in progress, and will be prioritized by representatives of the military Services.

FY 2004 Plans

A Program Research and Development Announcement process is in progress, including development of a Broad Agency Announcement, for selection of which T&E technology issues for embedded instrumentation are to be addressed first from the following T&E technology challenges:

- Tactical MEMS GPS (Global Positioning System) /IMU (Inertial Measurement Unit) Integration: Leverage on-going IMU research to improve drift rate accuracy to less than one degree/hour. Increase device performance to withstand harsh environments and package the device with processing and power packages. Integrate GPS with IMU device to operate in MOUT or GPS jamming environments.
- Self-Contained Module for Test and Evaluation: The goal of the project is a low cost, one cubic inch TM-on-a-chip system utilizing state of the art MEMS technology. The system includes plug and play architecture and standard interface module. Technical challenges for the project include size and power consumption reduction, encryption device constraints, transmit and receiver design. Sensors to be integrated for TM include inertial, acceleration, pressure, strain and temperature measurement. Sensors must be able to withstand severe tactical environments.

- Platform instrumentation sensor bus: Develop the interface logic necessary to create smart sensors exclusive of the physical layer. Leverage commercial bus standards to develop Field Programmable Gate-Array (FPGA) based prototypes and develop the integrated circuits required. Must address wired and wireless requirements.
- Tunable Transceiver: Leverage technology programs to develop multifunction, multiband, tunable transceivers for multiple telemetry applications. Miniaturize to embed into systems under test. Integrate with training requirements. Include conformal antenna investigations to match data link frequency. Also leverage RF MEMS efforts for miniaturization.

Inherent to these T&E capability needs is to be the accomplishment of:

- Miniaturization and reduced-weight instrumentation packaging
  - Exploit microelectromechanical systems and nanoelectronics
  - Improved sensor techniques
  - Higher bandwidth data encryption
  - Human performance instrumentation (e.g., MOUT T&E)
  - Non-intrusive interfaces with critical operational components including the MIL-STD-1553 data bus
  - Conformal and non-interfering antennas
  - Survivable in harsh environments, such as hypersonic speeds or electronic warfare
  - Wireless data and communications transfers and distribution
  - Plug and play architecture for common usage
- Reductions in on-board power demands
  - Power sources including batteries (especially for humans-in-the-loop)
  - Power distribution and conditioning
- Instrumentation command and control
  - Remote and artificial intelligence transceiver frequency tuning and operations control
  - On-board missile and electronic warfare simulations
- Advanced algorithms
  - Greater accuracy time-space position information resolution from GPS and onboard inertial measurement sources
  - Data fusion
  - Missile simulations, and no-drop bombing and missile scoring
  - Electronic warfare simulations (including psuedo-closed loop) and stimulations
- Vehicle power lines as a data bus
- Conformal externally mounted instrumentation
- Electro-adhesives
- Small RF transceivers
- Plug-and-play open architecture designs (including bus standards) for integrated test and training applications
- Conformal, wideband antennas for efficient spectrum utilization

- Precision real-time TSPI algorithms (cm accuracy)
- Ultra tightly coupled, integrated M-code GPS/IMU modules for high dynamic vehicles
- High anti-jam signal processing techniques for operations in an electronic warfare and jamming environment
- Smaller, higher capacity recorders to support passive operation
- More powerful micro-processors to support advanced simulations
- Compact and stable timing reference units
- Smaller, enhanced power sources
- Passive devices for improving ground truth measurements, such as for attitude and miss-distance measurements.

FY 2005 and Future Plans:

The T&E technology issues identified in FY 2004 for this project will continue to be worked.

C. (U) OTHER PROGRAM FUNDING NA

RDT&E PROJECT JUSTIFICATION SHEET (R-2a)				February 2003				
OPERATIONAL TEST AND EVALUATION, DEFENSE (0460) BUDGET ACTIVITY THREE, PE 0603941D				DIRECTED ENERGY TEST				
$'s in Millions	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	FY 2008	FY 2009
Directed Energy Test	0.000	1.202	1.944	4.084	4.584	6.913	9.807	15.210
RDT&E Articles	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

A. (U) MISSION DESCRIPTION AND BUDGET ITEM JUSTIFICATION

Directed energy (DE) weapons systems technologies, which primarily consist of HEL and high power microwave (HPM) sources, are outpacing test technologies. Advancements in HPM and HEL have created a new class of weapon systems in which energy is placed on a target instantaneously, with essentially zero time of flight. As such, traditional test techniques for evaluating conventional munitions (with flight times ranging from seconds to minutes, and that depend on various forms of physical contact for kill) are not applicable to DE systems T&E. These DE systems will precipitate a revolutionary change on future engagements, employments, concepts of operations, and T&E. Ground-, sea-, air-, or space-based lasers can be precisely focused on a target to provide surgical strike capability at very long ranges. Once on target, lasers affect the target from the outside by rapid heating, causing localized burn-through to create structural degradation or destruction and observable attributes of a hard kill. Conversely, high-power microwaves flood target areas with energy -- allowing for the engagement of multiple targets at the same time. High power microwaves affect the target from the inside through electrical system disruption and burn-out for a soft kill. These differences notwithstanding, both HEL and HPM have some very important common traits. Either type of directed energy travels to the target at the speed of light, is capable of graduated effects (deny, disrupt, degrade, and/or destroy), and can be used to minimize collateral damage. Current DE system and component testing usually includes two principal thrusts; how well is the weapon performing, and what is the specific interaction of energy and target.

Military utility of these weapons will be dependent on the knowledge acquired through T&E to know how much to trust the technologies under development and how best to use them. Other consequences of not providing adequate T&E capabilities for the new DE technologies and systems include:

- Not knowing whether they can be safely deployed

- Not knowing whether the system achieves the proper target kill rate
- Risk of apparent poor system performance during T&E leading to unjustified program cancellation
- Risk of fielding an ineffective system due to inadequate T&E
- Delays in meeting critical Transformation Objectives

DE technologies are transitioning into acquisition programs and advanced concept technology demonstrations (ACTDs) via multiple paths at a rapid pace. However, there is no vehicle to rapidly mature and transition technologies into the DE T&E infrastructure. DE programs either under development for acquisition or being worked as ACTDs include, but are not limited to: HPM command and control warfare/information warfare, Army Advanced Tactical Laser, Air Force Airborne Laser, Army Tactical High Energy Laser, Navy Free Electron Laser, Solid State Laser, and the Space-Based Laser. These revolutionary operational capabilities will require revolutionary operational test and evaluation (OT&E) scenarios, technologies, and analysis tools.

B. (U) ACCOMPLISHMENTS/PLANNED PROGRAM

	FY 2002	FY 2003	FY 2004	FY 2005
Directed Energy Test	0.000	1.203	1.944	4.084
RDT&E Articles	N/A	N/A	N/A	N/A

FY 2002 Accomplishments:

Roadmapping of the T&E needs for survivable instrumentation was achieved via workshops.

FY 2003 Plans:

The DE focus area project will begin investigating T&E technology issues in FY 2003. Issues to be investigated first are currently in the selection phase, and, as a minimum, are intended to develop technologies and processes for the remote sensing for DE, in particular, HEL weapon systems undergoing test and evaluation.

FY 2004 Plans

Further investigations will focus on several key technologies that are specific or in direct support of remote sensing for HEL and HPM testing. For HEL testing, this dictates a requirement for remote sensing of the various lasers and their interaction effects with atmosphere and targets. This includes, but is not limited to, data associated with imaging, spectral content, laser-target interaction signature, “kill” mechanism, atmospheric refraction, scattering, absorption and propagation data, beam quality, jitter, energy fluence on target, aim point maintenance, data recording, spectrally efficient data links, high-rate image/data reduction and visualization tools, etc. Investigations will include:

- HPM and HEL power measurement on target: Examine various sensor approaches or materials that can be incorporated into airborne and ground targets to measure DE on target. Sensors/material must be able to be applied/integrated into a variety of platforms, to include airborne and ground-based and provide for minimal interference with system operation to provide a measure of beam energy on target. Inability to collect DE on target will preclude ability to measure effectiveness of emerging DE weapon systems.

- DE-hardened flight termination system/range destruct package: study and assess requirements for DE "hardened" flight termination systems. These systems must be able to safely and reliably provide for termination of the target, even when high concentrations of DE are present on the target. This should include both HEL and HPM. Current flight termination systems may either be negated or prematurely initiated by the presence of RF energy or high-fluence laser energy. Impact of Flight Termination System failure due to DE could include damage to unintended targets, unrecoverable targets, threat to life and areas surrounding the test area.
- DE beam prediction/detection/display: develop capability to accurately predict and understand where HPM and HEL energy is actually projected is critical to T&E and safety. Wide spectrum, single substrate imagers study area seeks to enhance detection technology for imaging and detection of HEL beams from a variety of systems/sources. These enhancements would address limitations in spectral coverage of various limited spectrum, single substrate imagers. Current technology requires multiple sensor/optic combinations to cover the spectral range of existing HELs, which is extremely cost prohibitive. Single wide-spectrum imagers would eliminate the need for multiple, costly sensor/optics combinations.
- M&S to extend test results: Incorporate physics based models into virtual graphical representations of T&E ranges to provide 3-dimensional, geodetically accurate models of beam propagation, beam spread, lethal range, fluence on target, atmospheric effects. These models could be used to predict hazardous DE fluence and beam propagation for a given test scenario, plan and model RF or HEL fluence in a test or target area to rehearse test conduct and provide for a robust DE 3D Visualization capability for the T&E ranges. Current 3-dimensiomal models are based on digital terrain data and can incorporate time-space position information from various sources such as radar and GPS, but lack physics-based models to predict laser or RF weapon system performance.

Inherent to these needs is the requirement to adapt or develop technologies for:

- Survivable onboard instrumentation required to measure the DE beam on the target
    - Minimize impacts on target performance, signature and vulnerability
    - Measure effects on the target: thermal, structural or sensor
    - Provide data to determine performance margins and reasons for failure
- Off-board instrumentation required to provide an indication that the DE beam struck the target and the location struck
    - Determine target and debris trajectories
    - Measure atmospheric characteristics
    - Provide an in-band imaging sensor
    - Provide infrared (IR) imager for peak temperature estimate
    - Provide evidence of the degree of hard kill and soft kill
- Expedite DE S&T efforts that support M&S and algorithms for testing of advanced DE systems.
    - M&S validated by hard T&E data—M&S can then
        - Help create test scenarios and improve test planning
        - Enable rehearsals of planned tests to verify realism and cost effectiveness
        - Reduce the need for expensive field test assets, many iterations and long duration tests
- Facilitate evaluation of system performance otherwise impossible due to limited resources, environmental restrictions and safety issues.

- Real-time Multiframe Blind Deconvolution Algorithm
    - Explore potential to facilitate long focal-length imagery, including test ranges that need to image the HEL spot on a target
    - Explore efforts that support range safety during open air testing
- Risk assessment models for potential DE hazards, keep-out area determination, keep-out durations
- Protection from adverse bioeffects
- Prevention of on range collateral damage and off range damage
- Survivable command destruct package for targets

FY 2005 and Future Plans:

The T&E technology issues identified in for FY 2003 and FY 2004 will continue to be worked.

C. (U) OTHER PROGRAM FUNDING NA